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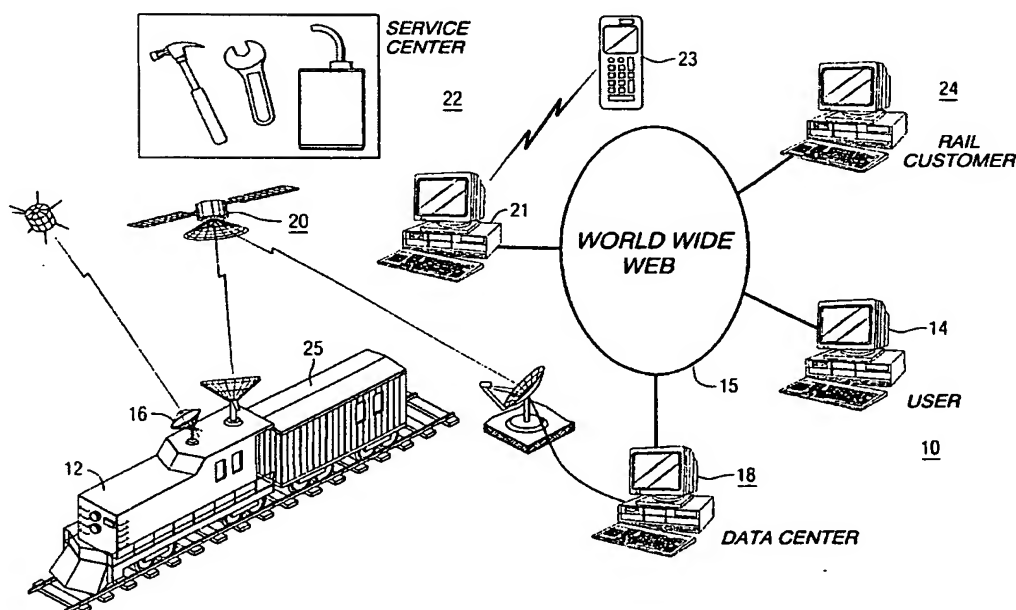
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(54) Title: APPARATUS AND METHOD FOR MANAGING A FLEET OF MOBILE ASSETS



(57) Abstract: A method and apparatus for managing a fleet of mobile assets, such as locomotives (12), utilizing remote data transfer (36, 40), real time data monitoring (122), predictive failure analysis (132), and integrated work order processing (172). A global information network (15) is used to facilitate the communication and presentation of high volumes of data to various parties (14, 18, 22, 24) involved in the process.

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APPARATUS AND METHOD FOR MANAGING A FLEET OF MOBILE ASSETS

The present invention relates generally to the field of managing a fleet of remote assets. In particular, the invention is described in the application of managing a fleet of locomotives.

BACKGROUND OF THE INVENTION

5 The management of a large fleet of mobile assets, such as a fleet of trucks, ships or railway locomotives, is a challenging logistical effort. There is continuing pressure for the owners of such assets to improve the efficiency of operations of the assets to remain competitive in the market place. For example, railroads must manage their fleets of locomotives to maximize the on-train time in order to remain competitive with alternative modes of transportation. The assignee of
10 the present invention is a supplier of locomotive engines and has developed numerous design features and services to maximize the efficiency of operation of its locomotives. The assignee of the present invention has also undertaken to provide integrated maintenance services to the owners of locomotives. Such services include the operation of a repair and maintenance service center and the supply of necessary
15 parts and labor. The coordination of the servicing of a large fleet of locomotives and the communication with the various parties involved in such efforts are monumental tasks.

United States patent 5,845,272 dated December 1, 1998, commonly owned with the present invention, describes a system and method for diagnosing
20 failures in a locomotive. While such a system and method has proven beneficial, further improvements in fleet management are desired.

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BRIEF SUMMARY OF THE INVENTION

Accordingly, a system and method are described herein for effectively integrating the diverse elements involved in the management of a fleet of mobile assets. The invention makes use of the data management powers of modern computer and global information networks by using such tools to collect, store, analyze, distribute and present information in a format and at a time when it can be used most effectively by people responsible for such assets.

The invention includes the aspects of real-time data collection from each of the mobile assets, computerized analysis of such data for failure detection and prediction, and the planning of maintenance activities responsive to such failure predictions prior to the asset being taken out of service. The planning of maintenance activities includes the selection of an optimal time and location for performing the work, with consideration given to the trends of the operating data, the availability of necessary repair resources, and other owner-defined criteria. Work planning further includes the automatic generation of appropriate work orders including the advance reservation of necessary service equipment, replacement parts and repair personnel. The various participants and stakeholders in these activities are provided with appropriate levels of information via a global information network. The information presentation power of the multi-media format of an Internet web site is ideally suited for accomplishing many of the communication functions necessary for implementing this invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the present invention will become apparent from the following detailed description of the invention when read with the accompanying drawings in which:

FIG. 1 is a schematic illustration of a communications network for managing a fleet of mobile assets.

FIG. 2 illustrates the steps of a method for managing a fleet of mobile assets.

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FIG. 3 is a block diagram of a system according to the invention for communicating data from a mobile asset.

FIG. 4 is a block diagram of the monitoring station apparatus of the system shown in FIG. 3.

5 FIG. 5 is a block diagram of a vehicle maintenance management method.

FIG. 6 is a block diagram of a system for conducting a remote inbound inspection of locomotives.

FIG. 7 illustrates an apparatus and method for generating work orders.

10 FIG. 8 illustrates a web page showing a route map for mobile assets.

FIG. 9 illustrates a web page showing the output of a search engine accessible via a global information network identifying the proximity of locomotives to a repair shop.

15 FIGs. 10-12 illustrate pages from a web site containing information related to the management of a fleet of locomotives.

DETAILED DESCRIPTION OF THE INVENTION

To effectively manage a fleet of mobile assets, it is necessary to avoid unexpected equipment failures and to accomplish maintenance and repair activities in a time efficient manner. There is a tremendous amount of information available
20 related to a fleet of mobile assets. Such information may include design information, real time operating data, historical performance data including failure probabilities, parts inventories, and geographic information related to the assets, cargo being transported with the assets, parts, personnel and repair facilities, etc. Key to
25 achieving efficient operation is the ability to communicate such information to people and places where it is needed, and to present the information in a format that makes it useful to accomplish the desired result.

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Accordingly, the inventors have envisioned the system 10 of Figure 1 for use in managing a fleet of mobile assets. Although illustrated and described with respect to a fleet of locomotives 12, the invention may be implemented with other types of mobile assets, such as trucks, ships, etc. Furthermore, the apparatus and method described herein is useful for managing not only mobile vehicles but also the cargo transported with such vehicles. The communication system 10 allows a variety of different types of users to obtain detailed and timely information regarding each of the mobile assets 12. Such users may include the transportation company 14 who owns and operates the locomotives 12, a customer 24 of the transportation company, personnel in a locomotive service center 22, personnel in a data center 18, and the engineer on-board each individual locomotive 12. The locomotives 12 may be equipped with a plurality of sensors for monitoring a plurality of operating parameters representative of the condition of the locomotive 12 and of the efficiency of its operation. The locomotive 12 may also be equipped with a GPS receiver 16 or other satellite based or local instrument for determining the geographic location of the locomotive 12. Data regarding the location of the locomotive 12 and its operating parameters may be transferred periodically or in real time to a data base 18 by a data link 20, such as a satellite system, cell phone, optical or infrared system, hard-wired phone line, etc. The assignee of the present invention operates such a data center 18 at its Monitoring and Diagnostics Service Center (MDSC) in Erie, Pennsylvania. Affiliated with such a data center 18 may be one or more service centers 22 where the locomotives 12 are taken for repair and maintenance services.

As illustrated in Figure 1, the data center 18 and service center 22 may both be linked to a global information network, such as the Internet 15, by known types of data connections. Such links may typically be a computer interface through an internet service provider. The Internet and World Wide Web provide a means for communicating between the data center 18 and service center 22. Furthermore, these facilities may also be in communication with the transportation company user 14 via an Internet connection. Customers 24 of the transportation company or other members of the public may further be in communication with these facilities through

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Internet links. Because the Internet 15 and known web page formats provide a means for communicating data and information in a multi-media format, such a global information network is a useful communication tool for displaying and communicating the large amount of data that may be associated with the operation of a fleet of mobile assets 12.

Figure 2 illustrates a method 28 for managing a fleet of mobile assets that may be implemented by using a communications system 10 as illustrated in Figure 1. Each mobile asset may be uniquely identified, such as by an identification number, as in step number 30 of Figure 2. One or more identifiers may also be associated with the cargo being transported with the mobile assets 12. For the embodiment of a fleet of locomotives 12, the operating parameters of each of the locomotives 12 may be monitored 32 by the on-board sensors. Preferably, such operating parameters are monitored in real time, and data related to these operating parameters is available for communication to a data center 18 wherever appropriate. The location of each asset is also determined 34, such as by using a GPS system or by otherwise identifying the locomotive to a particular location on the rail line. Data regarding both the location and the operating parameters for each locomotive 12 may be periodically downloaded 36 from an on-board data file to a centralized data base 39. In the event that a critical fault is identified 38 in one of the systems of a locomotive, it may be preferred to download data from the locomotive immediately 40 upon recognition of the fault. The timing of the download may also be determined based upon the availability and quality of the data link 20 between the locomotive 12 and the data center 18.

The database 39 located at the data center 18 may also include data representing inspection reports 42, maintenance records 44, and design information 46 related to the specific vehicles included in the plurality of mobile assets. For example, if a locomotive engine 12 is returned to a service center 22 for a periodic inspection and maintenance visit, information regarding the results of the inspection and maintenance activities may be used to update the database 39 for that particular locomotive 12. The database may also be updated 39 if the designer of the

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locomotive 12 provides any revised design parameters 46, such as a new part number for an upgraded component. The quantity of data in such a data base may be immense when considering the number of vehicles in some fleets, and when considering the amount of data that may be collected on a periodic basis regarding the performance of each of the vehicles. However, the computing power of modern data processing equipment makes it easy to analyze 48 such a database. Various data processing routines may be used to generate performance reports 50 regarding each of the individual assets or the fleet as an entirety. Statistical data 52 may be calculated to aid in the analysis of the operating parameters of the fleet.

In order to effectively utilize the vast amount of data that may be available regarding a fleet of mobile assets, the output of the analysis 48 of such data must be effectively displayed and conveyed to an interested user 14. There may be more than one user 14,24 interested in the data, and the level of detail of interest may vary from time to time. The inventor has found that an Internet web page is an effective means for communicating such data and information. An Internet web page may be updated 56 to reflect the performance reports 50, operating statistics 52, and/or current location map 54 for the fleet of mobile assets. One or more such web pages may be utilized with appropriate hyperlinks to additional web pages. By nesting related web pages, the level of detail presented to the user 14 may be controlled by that user. For example, a location map 190 of FIG. 8 illustrating the current geographic location of each of the locomotives 12 owned by a transportation company may include a hyperlink 192 at the indication of the location of each of the locomotives 12. Such a map may also illustrate the location of service facilities. Similarly, for a fleet of trucks, a road map may be generated showing the location of each truck along with its route. By constructing such a map in a web site format, a hyperlink 192 may be provided on the map for each mobile asset to connect the user to an interconnected nested web page containing additional information regarding that particular vehicle. For example, while the location of the mobile asset may be seen on map 190, by double clicking a cursor on the symbol for a single locomotive 12, the speed, destination, route, cargo information, fuel level, crew information, and other

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operating information for that locomotive may be viewed on nested web pages. One user, such as a customer 24 of the transportation company, may only be interested in the location of the train. Another user 14, such as a service engineer employed by the railroad, may be interested not only in the location of the locomotive but also in the amount of fuel on board or other operating parameter. Both such users 14,24 can quickly obtain the information they need by a simple point and click operation using known Internet browser technology.

Known search engine software technology may be provided 70 to allow a user to identify desired information related to the mobile assets 12 via the global information network 15. Access to an appropriate web page containing the desired information may then be provided via hyperlink directly from the search engine.

An Internet web page display used with the present invention may incorporate the full power of the multi-media capabilities of a global information network 15. For example, the location map 54 may include the use of color to indicate a readiness status for each locomotive, for example, green for a properly functioning locomotive, yellow for a locomotive exhibiting an anomaly in one of its operating parameters, and red for a locomotive having a critical fault. The user 14 of such information would be able to quickly assimilate a large volume of data and to have his/her attention directed to important portions of the data. Such a web page may also include links to additional pages containing drawings of component parts, specifications, or operating and repair manuals or other design parameters 46. In some instances, it may be advantageous to include video information on such a web site, such as still or motion video produced by the operator of the locomotive and transmitted directly from the mobile asset to show the condition of a component. Such video information may be accompanied by live audio information, including speech from the operator, thereby allowing the user 14, the operator located on the locomotive 12, and personnel at a service center 22 to conference regarding a developing anomaly. Communication over the global information network 15 using Internet Protocol allows packets of data to be communicated between different kinds

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of networks. The packets may consist of voice, text, video, audio or other types of data. The system 10 of Figure 1 is adaptable to make use of future platforms as they become available.

When a critical fault is identified 38, or an anomaly is found to exist 58
5 in one or more of the operating parameters, a service recommendation may be developed 60. Information regarding the anomaly 58, critical fault 38, and/or service recommendation 60 may also be uploaded 56 to an Internet web page. When appropriate, a user may be notified 62 that new or urgent information has been displayed on the Internet web page. The user may be notified 62 by an electronic
10 mail message, telephone call, fax or other simple form of communication. The user may then actively interact 68 with the web pages that present data regarding the mobile asset of interest. Such interaction may include a request by the user for additional information. Such a request would be transmitted to the locomotive operator or other appropriate person via the global information network connection,
15 and the response would be communicated in return.

The information available to the user on the Internet web page may also include information regarding services that are available 64 and/or a parts inventory 66 that may be important to any decision regarding a maintenance recommendation 60. Personnel located at a service center 22 may not only provide
20 data for the user 14, but may also receive a communication from the user 14 regarding a planned maintenance activity, thereby facilitating the scheduling of maintenance activities at the service center 22.

The advantage of the communication system 10 of Figure 1 and method 28 of Figure 2 may be appreciated by considering a three locomotive train 12
25 operating in a relatively flat terrain on its way to a mountainous section of a rail line. Because the three locomotives are operating at reduced capacity along the flat terrain, the operator of the locomotives who may be physically sitting in the front locomotive may not be aware that a degraded condition has developed in the third locomotive. For example, a degraded cooling system may cause the third locomotive to throttle
30 back to a reduced power output. Because the first and second locomotives are able to

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provide the necessary power, the progress of the train is unimpeded. Should this degraded condition continue to go unnoticed, the train would be unable to negotiate the mountainous terrain that it is approaching later in the journey. However, on-board sensors on the third locomotive identify the degraded cooling condition and data related to the degraded condition is immediately downloaded 40 to the data center 18 to update the data center database 38. Computers and/or personnel located at the data center 18 may analyze the data 48 and identify that the anomaly exists 58 and determine that a maintenance action 60 is recommended. For example, if a fan motor controller has developed a malfunction, a maintenance recommendation 60 to replace the control panel may be generated. A web page display showing the location of the locomotive would then be promptly updated 56 to show the degraded condition, and the railroad maintenance personnel are notified 62 by an electronic mail message that is automatically generated at the data center 18. The e-mail will include a Universal Resource Locator (URL) directing the maintenance personnel to an Internet web page containing information regarding the degraded condition and the recommended maintenance activity. The maintenance personnel then view the available parts inventory 66 illustrated on another web page to verify the availability of the required control panel in a service center 22 located along the route of the locomotive 12. In this example, a user 14 is able to utilize the power of a global information network 15 web page presentation to quickly assess the importance of anomaly affecting one of a fleet of mobile assets and to assess various options for addressing such anomaly. For this example, the degraded locomotive may be repaired prior to the train becoming stalled on a mountainous section of the track, thereby avoiding a large out-of-pocket expense and a costly schedule delay for the transportation company. The speed of communication via the Internet and the breath of information that may be effectively communicated via an Internet web page make the communication system 10 of Figure 1 and the method of managing assets 28 of Figure 2 beneficial for a large fleet of mobile assets distributed over a large geographic area.

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Access to an Internet web page containing important information regarding a fleet of mobile assets may be restricted to only those users having appropriate authorization to access such data. For example, information derived from the analysis 48 of the data base may be displayed on a password protected Internet web page. Only authorized users 14,24 would then be provided with the password necessary to gain access to the web page. Similarly, information received from a user and used to update the web page 56 may only be accepted as authentic if the user enters an appropriate password to confirm his/her identity. Other protection measures such as encrypting data may also be used. In some cases it may be desired to have at least a portion of the information displayed on an Internet web page be made publicly available. For example, it may be desirable to make the location map 54 for at least a portion of the mobile assets available for public viewing. In the case of a railroad transportation company, the location of passenger trains may be information that can be made available on a public Internet web page, whereas the location of freight trains may be limited to only specific industrial customers of the railroad company.

The present invention may further include a capability for predicting vehicle failure and for using such predictions to plan repair and maintenance work for each individual asset. One data is collected from the mobile assets, it may be used to develop a variety of types of information regarding the mobile assets. Such a capability includes monitoring on-board systems parameter data transmitted from each vehicle as it is operating; determining whether any of the monitored data is out of a predetermined range; calculating trends for monitored data determined to be out of range; identifying any system fault; predicting when such system is likely to fail unless corrected; and predicting which, if any, system must be corrected to avoid vehicle failure, developing a service recommendation, and communicating the service recommendation via a global information network. An apparatus to accomplish such steps is generally identified by numeral 110 of Figure 3, and it comprises a communication element(s) 112 and a monitoring station 114. Communication element(s) 112 are carried by the remote vehicle, for example locomotive 12. The communication element(s) may comprise a cellular modem, a satellite transmitter or

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similar well-known means or methods for conveying wireless signals over long distances. Signals transmitted by communication element 112 are received by monitoring station 114 that, for example, may be the maintenance facility 22 or data center 18 of Figure 1. Monitoring station 114 includes appropriate hardware and software for receiving and processing vehicle system parameter data signals generated by locomotive 12 from a remote location. Such equipment, as illustrated in block diagram form in FIG. 4, comprises receiving element 116, processing element 118, and man-machine interface element 120.

Examples of suitable receiving element 116 include a satellite communications receiver or cellular communications receiver. Processing element 118 may comprise a processor, memory and modem or Integrated Services Digital Network (ISDN) adapter of a conventional personal computer or workstation coupled with software capable of executing the functions represented in FIG. 4. Suitable processing element 118 may include a locomotive failure diagnostic system as described in U.S. Patent No. 5,845,272. Man-machine interface element 120 may include a monitor, keyboard, mouse, printer and/or other related I/O devices for enabling interaction between a human operator and processing means 118. Monitored vehicle parameter data received by receiving means 116 is communicated to processing element 118 wherein it is processed in the manner shown in FIG. 5.

Many vehicle system operating parameters are monitored, and trends are calculated on a subset of those parameters, or on all of the parameters. Among the parameters which may be monitored for locomotives are ambient air temperature, train notch, total track and force power, total voltage, total amps, software versions, engine RPM, engine temperature, crankcase pressure, dynamic braking, battery voltage, and voltage and amperage for all auxiliary motors. For other vehicles, other sets of parameters may be monitored. For a turbo-charged diesel truck, for example, monitored parameters may further include vacuum, fuel injection pressure, intake boost pressure, throttle position, etc. The monitored parameters may also include measurements of data important to the cargo 25 being transported by the mobile asset, for example the temperature in a refrigerated railcar or highway trailer.

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Referring to FIG. 5, there is shown a block diagram of the operations performed by processing element 118 upon receipt of vehicle systems parameter data transmitted by communication element 112. Upon issuance of a transmission request from monitoring station 114, communication element 112 preferably continuously transmits the data and receiving element 116 preferably continuously receives the data. Using receiving element 116, processing element 118 monitors the data as indicated at 122. A first determination 124 made by processing element 118 is whether any of the data is outside of an acceptable range for any of the vehicle systems being monitored. If the processing element identifies out-of-range data, it executes a routine 126 to calculate whether the data suggests one or more trends suggestive of possible or actual impairment or failure of the vehicle systems being monitored.

The trends are calculated by comparing values for a given parameter over a period of time and comparing those values with historical data for identical vehicle systems. This enables rapid and accurate correlation of trending data with a dedicated fault occurrence experience database. The trends are preferably calculated based in part on prior downloads collected in the database. The database is preferably continually updated and may be stored in the memory of processing element 118, elsewhere at the monitoring station 114, or off-site whereby it may be accessed on-line.

An example of a trend that may indicate a system fault would be a crankcase overpressure trend from negative to positive. Such a condition may be suggestive of a cylinder or piston problem or excessive engine wear. Processing element 118 is preferably capable of linking the results of several observed trends to more precisely diagnose a problem. For instance, the aforementioned crankcase overpressure trend may be coupled by processing element 118 with an observed trend in electronic fuel injection parameters to more clearly determine the cause of the problem.

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Once an unfavorable trend is detected, it is identified by processing element 118 with a stored fault code as indicated at 128. Fault codes corresponding to a wide variety of faults may be stored, and trends may be calculated for some or all of them. Examples of faults that may be categorized include, without limitation, overcurrents, flashovers, crankcase overtemperatures, crankcase overpressures, communication failures, electrical ground failures, air conditioner converter failures, propulsion system faults, auxiliary system faults, propulsion motor faults, auxiliary motor faults, auxiliary system charging faults, engine cooling system faults, oil system faults, control wiring faults, and microelectronics faults.

As indicated at 130, following identification and categorization of a fault, processing element 118 then prioritizes the fault. The fault prioritization process involves comparing the identified fault code with a historical fault database whereby the fault may be classified as critical, restrictive, or both critical and restrictive. A critical fault is one that will cause imminent vehicle shutdown if not immediately corrected. Examples include, without limitation, serious engine problems, main and auxiliary alternator grounds, coolant or oil pressure loss and microelectronics failures. A restrictive fault is one that, although not likely to cause imminent vehicle shutdown, impedes vehicle performance. A restrictive fault is likely to become progressively worse and may degenerate into a critical fault if not timely addressed. Examples of restrictive faults include, without limitation, an overheated engine or the loss of one or more traction motors, each of which deplete horsepower and may cause other strain on the engine or other systems of the vehicle.

After a fault has been prioritized, processing element 118, as indicated at 132, predicts which vehicle system is likely to fail. Additionally, processing element also predicts the estimated time of failure, preferably expressed as an approximation of the distance (in miles or kilometers, for example) the vehicle can be safely operated before it must be shopped prior to failure or the amount of operating time prior to failure. The optimum time the vehicle should be shopped is determined by resorting to the relevant trend data for the identified fault and comparing that data

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with a projected time-of-failure knowledge base which has been inputted into the database for the calculation.

As indicated at 134, processing element 118 is also preferably programmed to instruct a human operator at monitoring station 114: (1) whether to
5 correct the fault prior to scheduled maintenance of the vehicle, (2) when to correct the fault, (3) what fault to correct (preferably including what parts or components of the vehicle to repair), and (4) the optimal facility at which to correct the fault. The optimal repair facility is dependent upon the proximity of the vehicle to a facility and whether the facility has the capability, including parts, service equipment and
10 personnel expertise necessary to repair the fault. Personnel at the service center are alerted to the planned arrival of the locomotive at step 135.

The data monitored at step 122 may include data regarding the cargo
25 being transported by a mobile asset 16. Such data may be used to develop information regarding the cargo, and such information may be distributed via the global information network 15. A web site may be developed including information
15 of interest to the owners of the cargo 25, such as the location of the cargo, and such owners may be provided access to the respective web pages via secured or unsecured web access via the global information network 25. A route map such as is illustrated in FIG 8 may be posted on the global information network 15 to illustrate the location
20 of various cargo loads. Two-way communication may be provided between a controller 24 for the operation of the mobile assets 16 and the owners 14 of the cargo 25.

The apparatus and method of the present invention may also include improvements in the processing of a mobile asset through the repair facility 22 of
25 FIG. 1 when maintenance/repairs are necessary. FIG. 6 illustrates in block diagram form a system for performing an inspection of a remote inbound vehicle, and for planning the maintenance/repair activities on that vehicle before it arrives at a service location. Such a process begins by identifying an inbound mobile asset, such as a locomotive 12, and its scheduled maintenance date 141. The maintenance schedule
30 may be maintained on a computer in the service center 22 or at any other convenient

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location accessible through the global information network 15 of FIG. 1. Prior to arrival at the shop, a signal is sent to the communication element 112 of FIG. 3, such as an on-board computer, and instructs it to transmit data on all monitored parameters 142. The service personnel and service center computer have access to a vast amount of historical and experiential data pertaining to the systems used in various locomotive models, and they use such data according to an algorithm to determine which maintenance and repair operations are required, advisable, and optional 143 for the particular inbound locomotive. A report is generated and sent to the owner of the asset, such as via an Internet web page, to identify such operations while the vehicle is still inbound. Decisions 144 are made as to which of the advisable and optional maintenance operations will be performed when the locomotive arrives at the shop. Maintenance personnel may then begin preparations for the repair activities 145 prior to the mobile asset arriving at the repair facility. The system envisions beginning repair operations 146 immediately upon arrival of the asset 12 at the service location 22, obviating the requirement of a time-consuming inspection and decision-making process after arrival in the shop. Information regarding the status of a service activity may also be distributed via the global information network.15. Once a repair is completed and the locomotive is returned to service, performance data may again be monitored 147 to conform a satisfactory completion of the service activity, and information regarding the satisfactory completion may be distributed via the global information network.

The step 143 of determining which operations are recommended may include the analysis process illustrated in FIG. 5. Trends are calculated 126 by comparing values for a given parameter over a period of time and comparing those values with historical data for identical vehicle systems. This enables rapid and accurate correlation of trending data with a dedicated fault occurrence experience database. The trends are preferably calculated based in part on prior operating data that has been downloaded and collected in the database. The database is preferably continually updated and may be stored in the memory of the shop computer or off-site at data center 18 where it may be accessed on-line via the network 15 of FIG. 1.

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The present invention enables service personnel to reliably and quickly retrieve a vast amount of archived information directly onto the job floor, either via a kiosk 21 located within the service facility 22 and/or with portable hand-held communication and display units 23 that the service personnel can take with them right to the locomotive 12. Such data portals 21,23 may communicate to a central computer via electromagnetic signals, such as RF signals, or on-line via the Internet or via an intranet of the service provider. The data portals advantageously display the information directly at the work site location. It will be appreciated that the present invention contemplates the use of mobile wireless, web-access devices that could directly access the intranet of the service provider.

Electronic Service Delivery (E-izing) as contemplated by the present invention is a broad term used to describe the result of many applications to be utilized at a service application site 22. It involves streamlining and standardizing multiple servicing processes, as well as providing the users with all the information they need to maintain and repair a product on location. A first data portal may be a kiosk 21, e.g., a PC-based information stand that contains all the technical and safety information that is currently available in hard copy. Information is made conveniently available at the click of mouse, the touch of a screen, a voice command, etc. A second portal may be a handheld device 23 that could utilize the kiosk 21 as its hub and may be used for displaying real time information relevant to the tasks involved in inspecting and repairing the product 12. The present invention may further enable the display of service-related information on a monitoring board to allow service personnel to quickly and accurately know on a real time basis the status of every piece of equipment being serviced at the service site 22 or at other sites. By way of example, the information transmitted through each of these portals 21,23 may be technical information available in hard copy but enhanced through suitable multimedia applications, such as audio and/or visual drill downs, and/or wizard applications that empower the service personnel to make uniformly correct decision across all the service sites.

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The electronic data delivery system of the present invention allows for improving field service operations by applying e-Business technologies to replace manual paper based processes. The business benefit will include improved availability of the asset by reducing the cycle time of the repairs and to have higher quality repairs. In addition, other processes, such as inventory management, will be improved to have the correct part available when needed.

As shown in FIG. 7, a work order flow module 150 is used to control the various repair processes. One exemplary step or action is to develop an accurate work scope 152 in response to a service recommendation, such as is developed at step 143 of FIG 6. Information will be electronically accumulated to develop the work scope, and at least part of this information may be communicated via the global information network 15 as illustrated in FIG 1. By way of example and not of limitation, the information may include the following: performance information from the product 154, repair history information 156, information from the customer 158, required and optional repairs 160, and information learned during inspection 162.

The next step is to use the work scope to determine the sequence of repairs 164 based on customer need 158, materials availability 166, and resource availability 168, and drawing upon customized or standard work steps stored in a data warehouse 169. The process will provide service personnel with the information needed to determine the order of repairs and to communicate to the craft workforce.

The execution of the repairs will take place 170 by directing the worker via the data portal 21,23. The work order 172 provided to the worker via the data portal will direct the worker through each repair that is needed. The completion of each step is recorded via the data portal to update the data warehouse 169 and to provide real-time repair status information via a monitoring board 174. A feedback loop will be used to update the current production configuration. The work order 172 will provide a more controlled and accurate repair process.

The information obtained from the work order completions will allow for monitoring the status of the repairs and will also allow customers 176 to get real-time status of their product in the repair cycle. The data will also be used to improve

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reliability of the product and to compare and improve field shop processes across field sites. Communication of such information can be efficiently accomplished via the global information network 15 of FIG. 1.

In operation, consider a scenario of how the present invention improves productivity and performance in a plurality of locomotive fleets by leveraging advanced communication, diagnostic, scheduling, data handling and locomotive repair technologies, thereby increasing train on time and up time. Envision a train operating along a rail route. Diagnostic modules are regularly monitoring the various subsystems of the locomotive to ensure operations stay within set parameters. For example, the onboard system may be configured to maintain optimal fluid conditions to maximize oil life without sacrificing either engine reliability or locomotive performance. If the onboard monitor recognizes trends outside predefined limits, the fluids management system highlights the abnormality on the locomotive indicating a potential concern. Based on the severity of the concern, the system may automatically call the remote diagnostics service center with the necessary data to confirm the diagnosis. Expert systems and/or expert personnel evaluate whether a faulty condition is developing outside of the normal boundaries and a corrective action may be proposed and communicated via a global information network. The recommended action may be supplied directly into the train control system. At this time, the data center or service personnel may evaluate the most logical repair location in terms of various criteria, such as train proximity, parts, repair equipment availability, manpower availability, etc. The service recommendation automatically triggers the creation of an electronic work order 172 within a service shop management system. A notification is then sent, such as via an e-mail message or by providing information on an Internet web page, to the service team detailing the parts and labor necessary for a timely and accurate repair.

The recommendation also sets a proximity trigger to notify the service shop when the locomotive is within a certain distance of the repair location. As soon as the service team receives information about the necessary repair, team members gather or reserve the parts, equipment and personnel needed to perform the corrective

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action 145. The approaching locomotive may automatically forward a notification message to the service repair shop indicating that it is approaching. Alternatively, the service personnel may utilize a search engine 70 to identify the proximity of locomotives to their respective service shop. An example of a web page presenting such information is shown in FIG 9. A hyperlink may be provided on this screen to connect the user with nested web pages showing more detailed information regarding a particular locomotive. Upon arrival of the train to the scheduled repair station, the locomotive is repaired by a service technician equipped with the necessary parts and the wireless handheld device 23 that contains the appropriate maintenance, safety and training instructions for the repair to be accomplished safely, quickly and accurately. Furthermore, plans may be made in advance of the train arriving at the service shop for the continued transportation of the cargo being transported by the train, thereby avoiding excessive delays in cargo delivery.

The service technician informs the service shop management system that the operation has been completed. The train continues on its route without delay. During its journey, the technology service center monitors the latest downloaded data 147 to ensure the problem has been corrected.

The global information network 15 facilitates the effective communication of many forms of information for improving the management of a plurality of mobile assets 12. A web site accessible through the global information network 15 and using standard Internet Protocol can present information in a variety of formats to satisfy the unique requirements of a variety of users. Such information may include failure predictions, service recommendations, the availability of service shops 22, parts and personnel, the location of a mobile asset 12 or its cargo 25, performance data, audio and video information produced on-board the mobile asset, two-way communication between a mobile asset 12 and a fixed location 14,18,22,24, statistical information regarding the availability of the assets 12, repair status information, etc. Web site technology, including interconnected web pages and hyperlink connectivity, may be used to present multi-media information. Example web pages from a web site created as part of the system 10 of Figure 1 are illustrated

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in Figures 10-13. Figure 10 illustrates a web page 200 providing hyperlinks to a variety of design documents for a locomotive. One such hyperlink 202 takes the user to an interconnected page having a specific troubleshooting guide. That page is illustrated in Figure 11. Web page 200 also includes the capability for the user to
5 conduct a search, such as by inputting a specific vehicle number 204. Figure 12 illustrates another web page 210 whereby best practices are shared by the posting of messages by various users. Here, again, various search capabilities are provided 212 to enable the user to use the information effectively, and various hyperlinks 214 provide easy connections to other associated web pages and functions. As bandwidth
10 capabilities increase and become less expensive, the benefits of the disclosed invention will become even more important.

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CLAIMS

What is claimed is:

1. A method for managing a fleet of mobile assets, the method comprising:

transferring data representing operating parameters from each of a plurality of mobile assets to a database

5 monitoring the data to identify at least one of the operating parameters for one of the mobile assets that is outside a predetermined range of values; and

predicting a failure in the one of mobile assets based upon a trend in the at least one of the operating parameters.

10 2. The method of claim 1, further comprising:

identifying a repair activity responsive to the at least one of the operating parameters;

selecting a repair location and schedule for the repair activity responsive to the predicted failure and the location of the one of the mobile assets.

15 3. The method of claim 1, further comprising:

alerting personnel at the selected repair location of the schedule for the repair activity;

developing a work scope of maintenance activities including the repair activity;

20 generating a work order containing information necessary to accomplish the work scope prior to the one of the mobile assets arriving at the repair location.

25 4. The method of claim 1, further comprising posting information related to the predicted failure on a global information network web page.

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5. A method for providing service to a mobile asset, the method comprising:

scheduling a first maintenance activity to be conducted on a mobile asset at a service location;

5 prior to the mobile asset arriving at the service location, downloading data representative of operating parameters for the mobile asset to a database;

comparing the downloaded data to other data stored on the database to identify a second maintenance activity to be conducted on the mobile asset at the service location;

10 preparing for the first and the second maintenance activities prior to the mobile asset arriving at the service location; and

conducting the first and the second maintenance activities on the mobile asset at the service location.

15 6. The method of claim 5, further comprising:

analyzing the downloaded data to identify an operating parameter outside a predetermined range;

evaluating a trend in the operating parameter outside a predetermined range to predict a failure in the mobile asset;

20 identifying the second maintenance activity in response to the predicted failure.

7. The method of claim 5, wherein the step of preparing further comprises:

25 developing a work scope to be conducted on the mobile asset at the service location; and

preparing a work order containing information necessary to conduct the work scope.

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8. The method of claim 5, further comprising posting information related to the first and the second maintenance activities on a global information network web page.

5 9. A method for managing a fleet of mobile assets, the method comprising:

downloading diagnostic data from each of a plurality of mobile assets to a database;

10 analyzing the diagnostic data to recommend a service activity for one of the mobile assets;

scheduling the one of the mobile assets to be serviced at a service location;

15 generating an electronic work order at the service location responsive to the service activity prior to the one of the mobile assets arriving at the service location;

executing the service activity in accordance with the work order.

20 10. The method of claim 9, further comprising providing information related to the service activity to a user via a global information network web page.

11. The method of claim 9, further comprising issuing a proximity notification to the service location indicative of the proximity of the one of the mobile assets to the service location.

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12. An apparatus for providing maintenance services to a fleet of mobile assets, the apparatus comprising:

a database;

5 a communication element associated with each of a plurality of mobile assets for communicating data associated with a plurality of operating parameters for each asset to the database;

a processing element for manipulating data in the database to identify a service activity for one of the mobile assets;

10 a work order module associated with the processing element adapted to produce a work order containing information related to the service activity.

13. The apparatus of claim 12, further comprising a data link to a global information network for presenting information related to the service activity on a web page.

15 14. A method for managing a fleet of mobile assets, the method comprising:

providing a data base;

monitoring a plurality of operating parameters for each of a plurality of mobile assets;

20 transferring data regarding operating parameters for each asset to the data base;

posting information derived from the data base on an Internet web page.

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15. The method of claim 14, further comprising:
determining the location of each asset;
transferring data regarding location for each asset to the data base; and
posting a graphical display of the locations of the assets on an Internet

5 web page.

16. The method of claim 14, further comprising:
storing maintenance records for each asset in the data base;
analyzing the maintenance records and the operating parameters to
develop a maintenance recommendation for each asset;
displaying data related to the maintenance recommendations on an
Internet web page.

10

17. The method of claim 16, further comprising the steps of:
storing data related to a parts inventory in the database;
analyzing the data related to the maintenance recommendations and the
parts inventory to generate a parts order list;
displaying data related to the parts order list on an Internet web page.

15

18. The method of claim 14, further comprising:
monitoring the operating parameters to identify an anomaly in the
operating parameters of a first of the assets;
developing a maintenance recommendation for the first of the assets in
response to the anomaly; and
posting the maintenance recommendation on an Internet web page.

20

25

-26-

19. The method of claim 14, further comprising the steps of:
monitoring the operating parameters to identify a critical fault in a first
of the assets;
transferring data related to the critical fault from the first of the assets
5 to the data base; and
displaying information related to the critical fault on an Internet web
page.

20. An apparatus for managing a fleet of mobile assets, the
10 apparatus comprising:
a database;
a communication element associated with each of a plurality of mobile
assets for communicating data associated with a plurality of operating parameters for
each asset to the database;
15 a processing element for manipulating data in the database to predict a
failure in one of the mobile assets; and
a data link in communication with a global information network for
posting information related to the plurality of mobile assets on a web page.

21. A method for managing a plurality of mobile assets, the method
20 comprising:
collecting data regarding each of a plurality of mobile assets;
using the data to develop information regarding each mobile asset; and
distributing the information via a global information network.

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22. The method of claim 21, further comprising:
analyzing the data to identify an operating parameter that is outside a
predetermined range for one of the plurality of mobile assets;
developing a service recommendation in response to the identified
operating parameter; and
communicating the service recommendation via the global information
network.

23. The method of claim 22, further comprising:
developing a work order responsive to the service recommendation;
and
communicating the work order via the global information network.

24. The method of claim 21, further comprising communicating the
information via a web site comprising a plurality of interconnected web pages
accessible via the global information network.

25. The method of claim 24, further comprising:
posting a first portion of the information related to each one of the
mobile assets on a respective web page; and
providing a hyperlink on each respective web page to a respective
nested page containing a second portion of the information related to the respective
one of the mobile assets.

26. The method of claim 24, further comprising:
providing a search engine for identifying desired information related to
the mobile assets via the global information network; and
providing access via a hyperlink from the search engine to at least one
of the plurality of interconnected web pages containing the desired information.

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27. The method of claim 21, wherein the step of distributing information further comprises:

linking a data center to the global information network;

5 linking a service center for the mobile assets to the global information network; and

posting a recommendation for a service activity for one of the plurality of mobile assets on a web site accessible via the global information network.

10 28. The method of claim 27, further comprising posting information regarding the status of the service activity on the web site.

29. The method of claim 22, further comprising:

undertaking a service activity on the one of the plurality of mobile assets; and

15 distributing information regarding the status of the service activity via the global information network.

20 30. The method of claim 29, further comprising posting one of the group of audio information and video information related to the status of the service activity on the web site.

31. The method of claim 29, further comprising:

collecting additional data regarding the operation of the one of the plurality of mobile assets following the completion of the service activity;

25 analyzing the additional data to confirm a satisfactory completion of the service activity; and

distributing information regarding the satisfactory completion of the service activity via the global information network.

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32. The method of claim 21, further comprising:
collecting data regarding cargo being transported by the respective
mobile assets;
using the data regarding cargo to develop information regarding the
5 cargo; and
distributing the information regarding cargo via the global information
network.

33. The method of claim 32, further comprising:
10 developing a web site including a respective web page containing
information regarding the cargo owned by each one of a respective plurality of
customers; and
providing access to the respective web pages via the global information
network to the respective plurality of customers.

15 34. The method of claim 33, further comprising providing two way
communication between a controller for the plurality of mobile assets and the
respective plurality of customers via the global information network.

20 35. The method of claim 32, wherein the information regarding the
cargo comprises the location of the cargo; and
further comprising providing a route map for the plurality of mobile
assets including the location of the cargo via the global information network.

25 36. The method of claim 21, further comprising:
using the data to develop information related to the operational status
of each of the plurality of mobile assets;
developing a web site containing the operational status information;
and
providing access to the web site via the global information network.

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37. The method of claim 21, further comprising providing two way communication between personnel located at a fixed location and personnel located on the plurality of mobile assets via the global information network.

5 38. The method of claim 21, further comprising;
 using the data to develop a failure prediction for at least one of the plurality of mobile vehicles; and
 including information related to the failure prediction on a web site accessible via the global information network.

10 39. The method of claim 38, further comprising providing information related to the availability of a service facility on the web site.

 40. The method of claim 21, wherein the step of distributing the information further comprises:

15 developing a web site presenting the information in the form of at least one of the group of video information and audio information; and
 providing access to the web site via the global information network.

20 41. The method of claim 40, further comprising developing the web site to include one of the group of video information produced on-board one of the plurality of mobile assets and audio information produced on-board one of the plurality of mobile assets.

25 42. The method of claim 21, further comprising:
 using the data to develop statistical information regarding the availability of the plurality of mobile assets;
 developing a web site to display the statistical information on a plurality of interconnected web pages;
 providing access to the web site via the global information network.

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43. The method of claim 42, further comprising:

using the data to develop information regarding repair activities on the plurality of mobile assets; and

including the information regarding repair activities on the web site.

5 44. An apparatus for managing a fleet of vehicles, the apparatus comprising:

a data collection element associated with each of the vehicles for obtaining data related to the operation of the respective vehicle;

10 a data storage element in communication with the data collection element for storing the data;

a processing element in communication with the data storage element for manipulating the data; and

a global information network linking the data collection element, data storage element and processing element.

15 45. The apparatus of claim 44, further comprising:

the processing element further comprising a failure prediction element for predicting a failure in at least one of the vehicles and posting a service recommendation for the at least one of the vehicles responsive to a failure prediction on a web page accessible via the global information network; and

20 a service facility having the capability for implementing the service recommendation and having a link to the global information network.

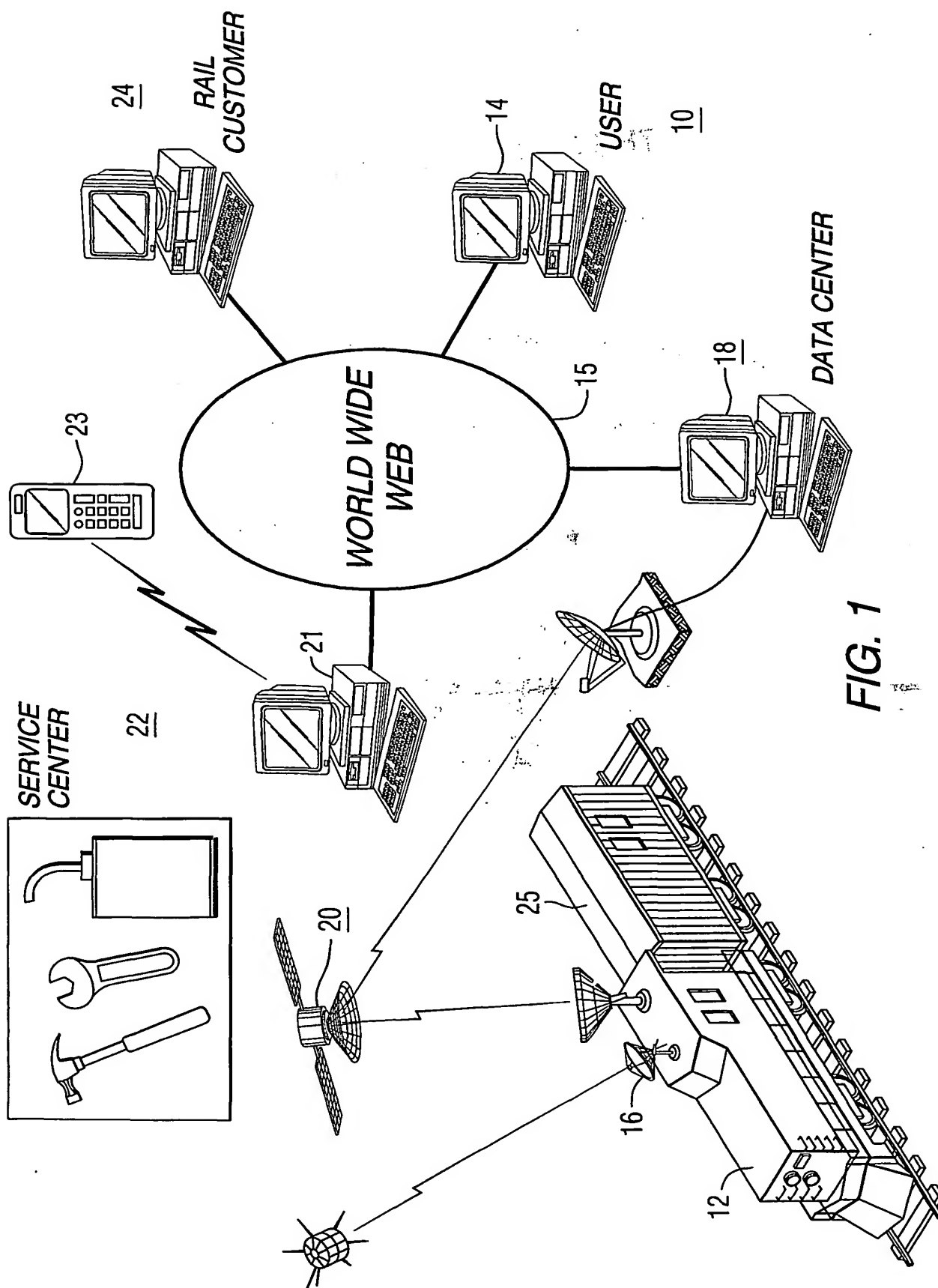
25 46. The apparatus of claim 44, further comprising a route map comprising a web page accessible via the global information network and in communication with the processing element for depicting information regarding the vehicles.

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47. The apparatus of claim 44, further comprising a web page accessible via the global information network and in communication with the processing element for depicting information regarding the vehicles.

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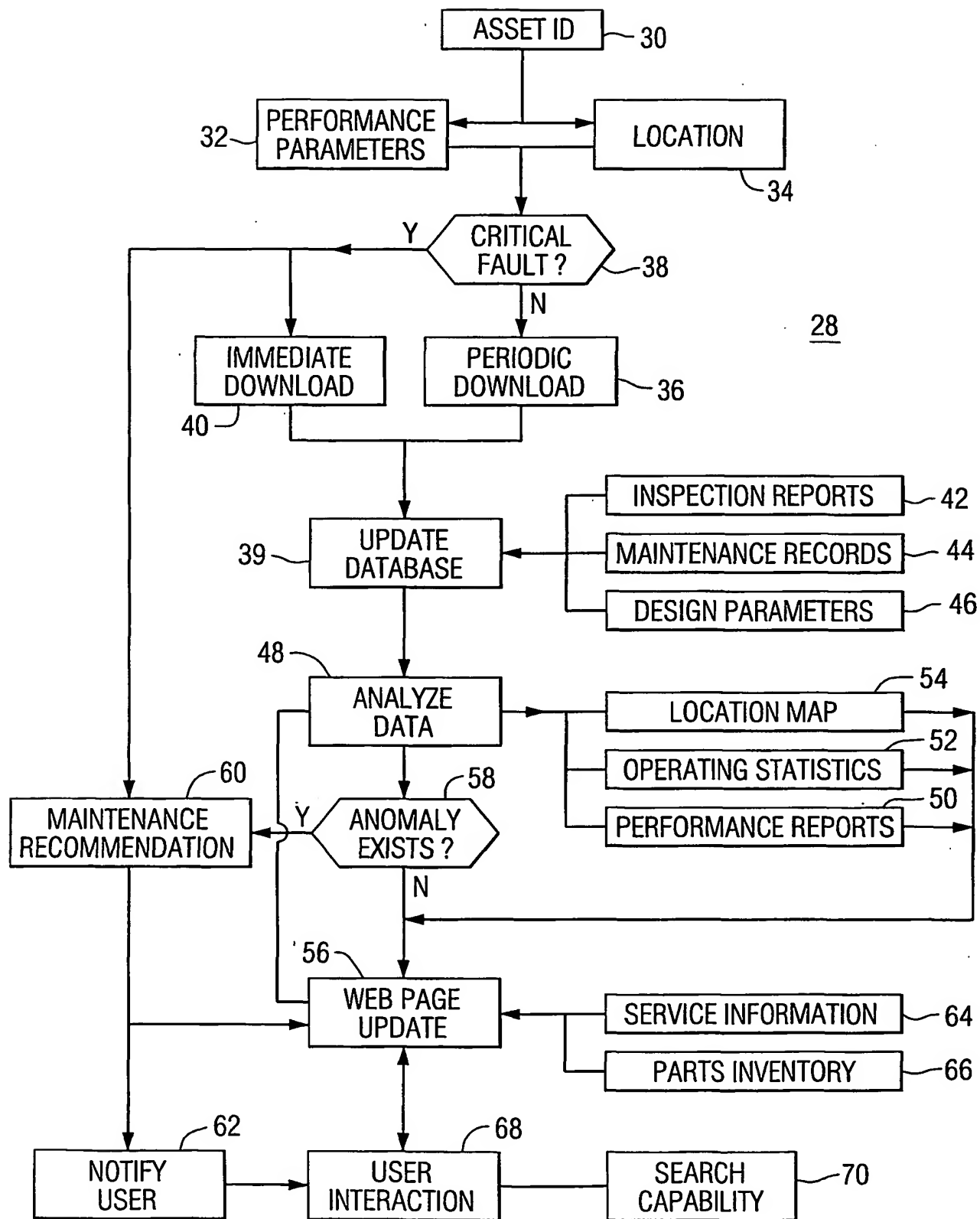
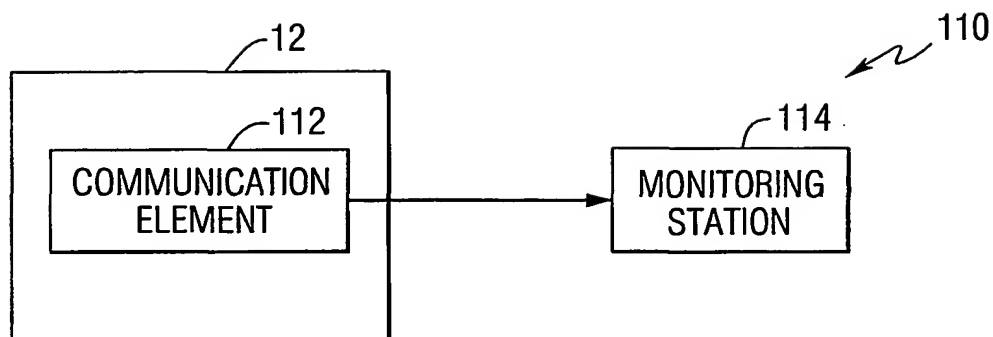
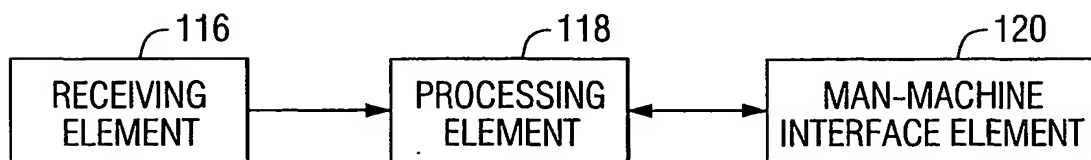


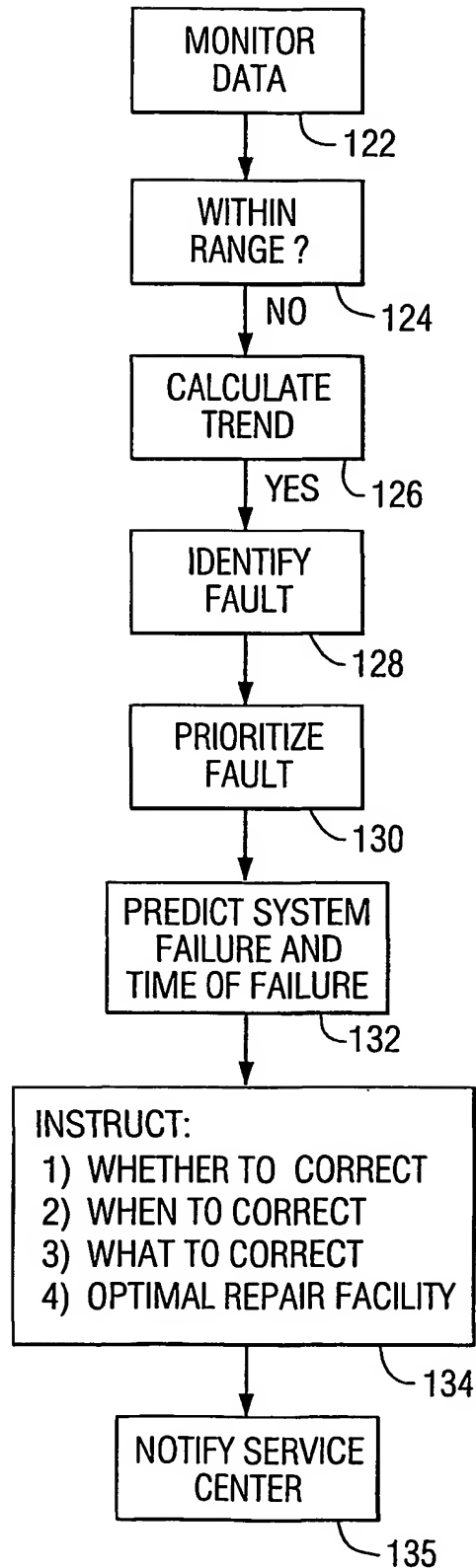
FIG. 2

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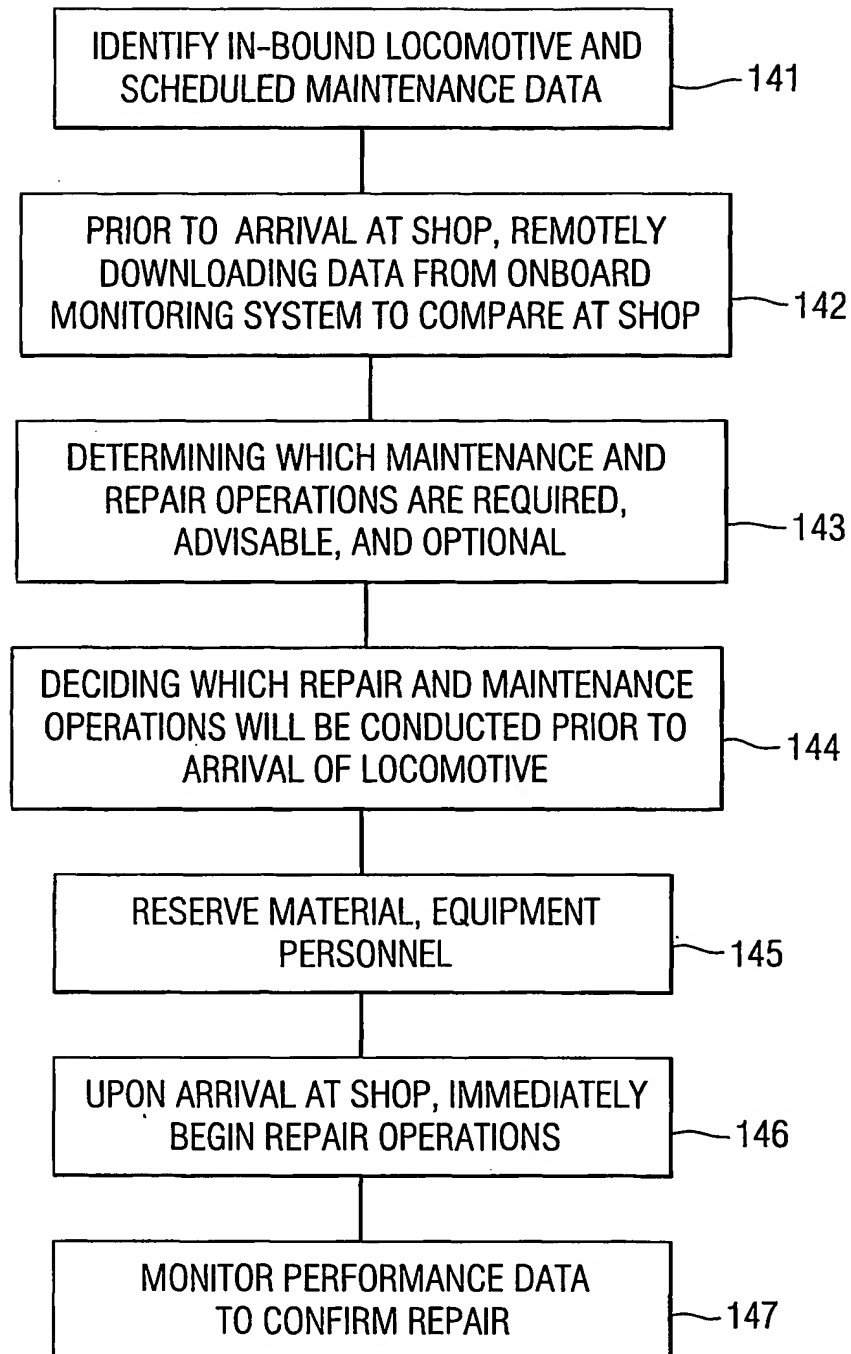
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**FIG. 3****FIG. 4**

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**FIG. 5**

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**FIG. 6**

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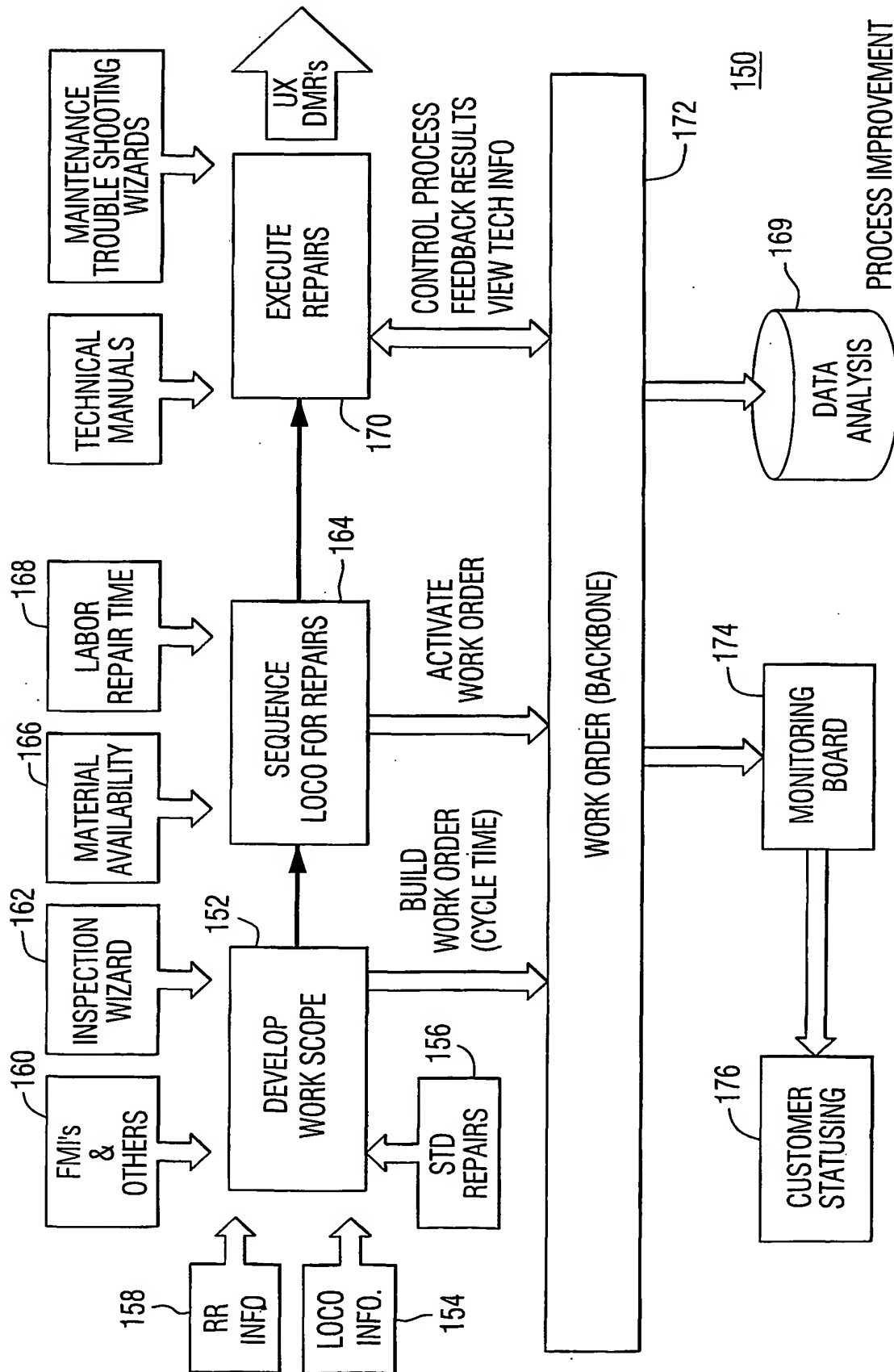


FIG. 7

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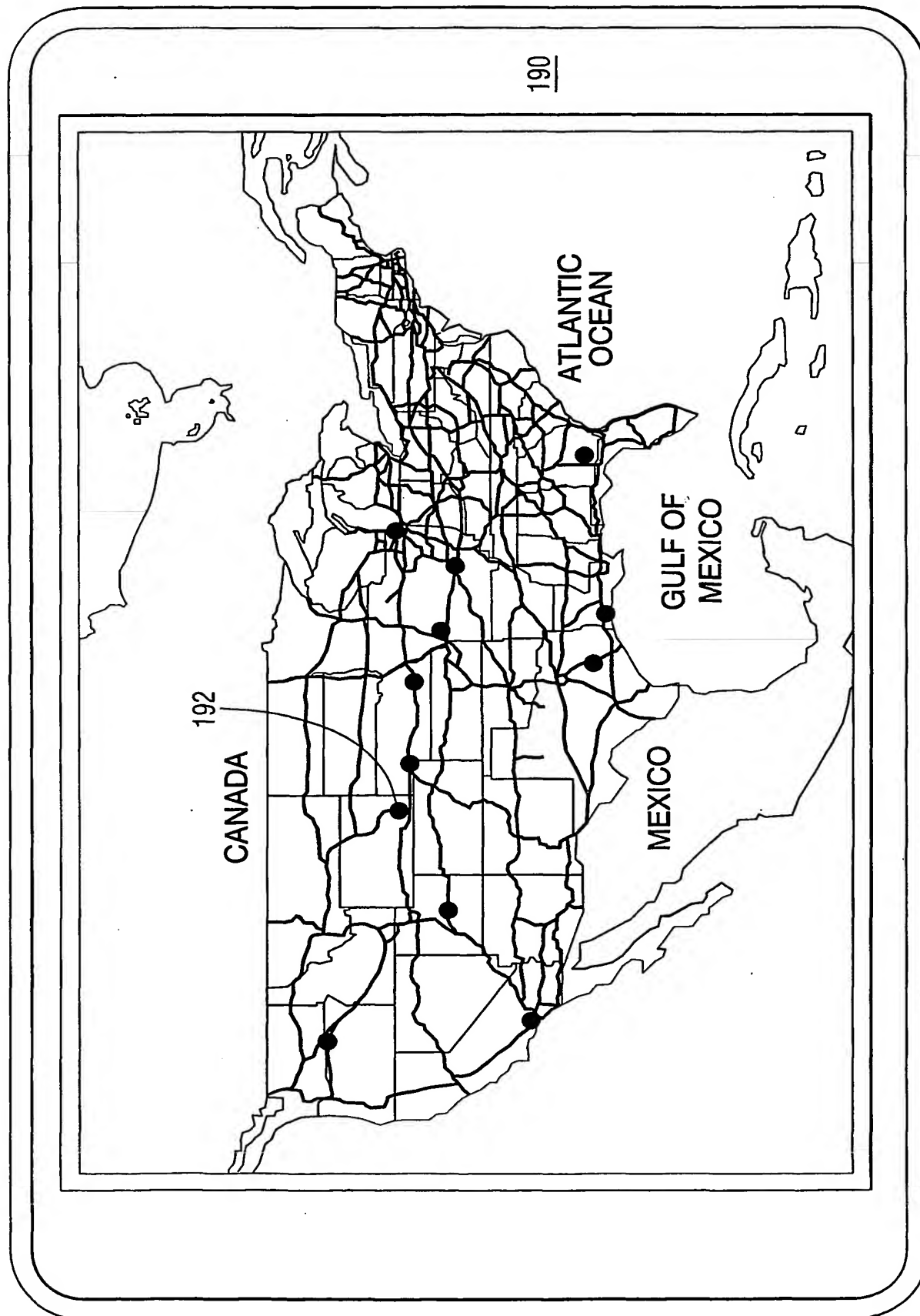


FIG. 8

LOCOMOTIVE CITY/STATE PROXIMITY

CITY:

STATE:

RANGE: MILES

SEND QUERY:

ALL LOCOMOTIVES WITHIN 100 MILE RADIUS OF LOS ANGELES, CA	
LOCOMOTIVE	LOCATION
8618	1.9 MILES E OF CARSON, CA
8444	1.9 MILES N OF MIRA LOMA, CA
8350	1.3 MILES NW OF PEDLEY, CA

FIG. 9

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GE TRANSPORTATION SYSTEMS

MY SERVICES

LOGGED IN: USER 1

HELP | PERSONALIZE | LOGOFF

HOME

MONITOR BOARD

BEST PRACTICES

PERSONALIZE THIS PAGE

CHOOSE GADGETS

CHANGE LAYOUT

CHANGE COLORS

ROAD NUMBER NAVIGATOR EDIT X

SEARCH

ADVANCED SEARCH

SAVED SEARCHES

LOCOMOTIVE TOOLBOX VER. 1.4 EDIT X

SOFTWARE UPLOADS AND FAULT CODE
DOWNLOADS...SEE HOW IT'S DONE!

BEGIN

FOUL ANALYSIS SEARCH EDIT X

STEP 1:

SELECT TYPE OF LOCOMOTIVE ☒ DASH8_DASH9

☐ AC4400

STEP 2:

TYPE WORD OR FAULTCODE TO
SEARCH

SEARCH

ADVANCED SEARCH

SAVED SEARCHES

INSTRUCTIONAL MATERIAL EDIT X

SEARCH

ADVANCED SEARCH

SAVED SEARCHES

PARTS CATALOG EDIT X

SELECT ROAD NUMBER OF LOCOMOTIVE:

ROAD NUMBER

NONE SELECTED ▼

GETS SERVICES PORTAL: MY PAGE

MY DOCUMENTATION EDIT X

TROUBLE SHOOTING GUIDES X

☒ DASH 8 TROUBLESHOOTING GUIDE

☒ DASH 9 TROUBLESHOOTING GUIDE 202

FMI'S

☒ 24 3520 FMI CDC MODIFICATION

☒ 24 3643 FMI CCBII FILTER MODIFICATION

☒ 24 3661 FMI CCBII PLUG INSPECTION

☒ 26 3711 FMI FUSE ELIMINATION

☒ 27 3473 FMI WATER TANK PRESSURE RELIEF VALVE

☒ 27 3728 FMI RADIATOR CAP REMOVAL

☒ 29 3700 FMI INJECTOR HOLD DOWN STUDS

☒ 30 3675 FMI WPS SENSOR REPLACEMENT

☒ 31 3723 FMI HEADLIGHT RESISTOR MODIFICATION

☒ 32 3412 FMI TOILET MODIFICATION

☒ 33 3278 FMI BRAKE LEVER CHANGEOUT

SPECIAL PROCEDURES

☒ BATTERY RELATED CHECKS

☒ BOSCH TOOLBOX RECORDING PROCEDURE

☒ CCBI UNITS HOW TO SET FLOW FOR A M61

☒ CCBI UNITS HOW TO SET FLOW FOR A M61

☒ CHECKING OVERSPEED 700 UP PHONEIX

☒ CHECKING OVERSPEED B60 1123 UNITS NON PHONEIX

☒ CW 44 BOSCH EGU TOOLBOX READINGS

☒ CYLINDER CUTOUT USING THE BOSCH TOOLBOX

☒ DISARM 2 WAY EOT

☒ HOW TO LOAD CAB FILES

☒ IES MOD SHEET

☒ AIR FLOW METER CALIBRATION

☒ DASH 7 CONTRACTOR EVALUATION

☒ QUANTUM EVENT RECORDER TEST SETUP

TORQUE VALUES

☒ DASH 8

☒ DASH 9

☒ AC4400

GENERAL SAFETY INFORMATION

☒ TO SAFELY LOCK-OUT TAG-OUT THE LOCOMOTIVE (MECHANICAL)

☒ TO SAFELY LOCK-OUT TAG-OUT THE LOCOMOTIVE (ELECTRICAL)

☒ EMPLOYEE SAFETY RULES

☒ MECHANICAL / P&M SAFETY RULES

FIG. 10

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GE TRANSPORTATION SYSTEMS

REV 0
84A207789

TROUBLESHOOTING GUIDE
FOR BNSF DASH 8 LOCOMOTIVES

TROUBLESHOOTING GUIDE FOR BURLINGTON NORTHERN SANTA FE (BNSF) DASH 8 LOCOMOTIVES

FIG. 11

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GE TRANSPORTATION SYSTEMS
MY SERVICES

BEST PRACTICE SHARING

HELP | PERSONALIZE | LOGOFF

HOME

MONITOR BOARD

BEST PRACTICES

SEARCH:

212

BOSCH HP PUMPS

SEARCH BY KEYWORD
ADVANCED SEARCH

POSTED BY SCOTT MACDONALD ON THURSDAY, JULY 13, 2000
STARTED TO TRACK HISTORY ON UNITS THAT HAVE FAILED FOR HP FAILURES.
RESULTS TO DATE:

A. UNIT 2567 - FAILED ON 6/26/00 FOR RIDING LOAD POT AS LOW AS 6%.
UNIT IN FOR INSPECTION 4/17/00.

AT THIS TIME PWR PISTON GAP WAS 0.367 AND ALL PUMPS FIRING...

POST NEW MESSAGE:
NEW MESSAGE

[CLICK TO READ MORE...](#) [REPLY...](#) [VIEW REPLIES...](#)

BEST PRACTICES:

UNIT 2579

POST BEST PRACTICE
VIEW BEST PRACTICES

POSTED BY SAGAR PATEL ON THURSDAY, JULY 13, 2000

PLEASE SHARE YOUR TROUBLESHOOTING EXPERIENCE ON UNIT 2579 WITH THE
FIELD SERVICE TEAM.

[REPLY...](#) [VIEW REPLIES...](#)

BROWSE MESSAGES:

BY CATEGORY
BY DATE

TM INSPECTION

POSTED BY SCOTT MACDONALD ON WEDNESDAY, JULY 12, 2000

WE DEVELOPED A NEW INSPECTION AND TRAINING PROCESS FOR ELECTRICIANS
WORKING ON TM CABLE GROUNDS. THE PROCESS CAN BE REVIEWED ONLINE AT...

RECENT MESSAGES:

7/11 PROBLEM1
7/10 PROBLEM2
7/10 PROBLEM3

[CLICK TO READ MORE...](#) [REPLY...](#) [VIEW REPLIES...](#)

WATER DUMP VALVES

POSTED BY STAN HAYS ON TUESDAY, JULY 11, 2000

A MAJOR RELIABILITY DRIVER ON THE DASH 8 FLEET IS FAILURES DUE TO
WATER DUMP VALVES.

A FAILURE MODE HAS BEEN IDENTIFIED AND THE VALVES WERE OVERHAULED.
THIS INFO IS TO BE SHARED WITH OTHER RAILROADS THAT USE THIS VALVE.

[CLICK TO READ MORE...](#) [REPLY...](#) [VIEW REPLIES...](#)

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FIG. 12

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International Bureau



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PCT

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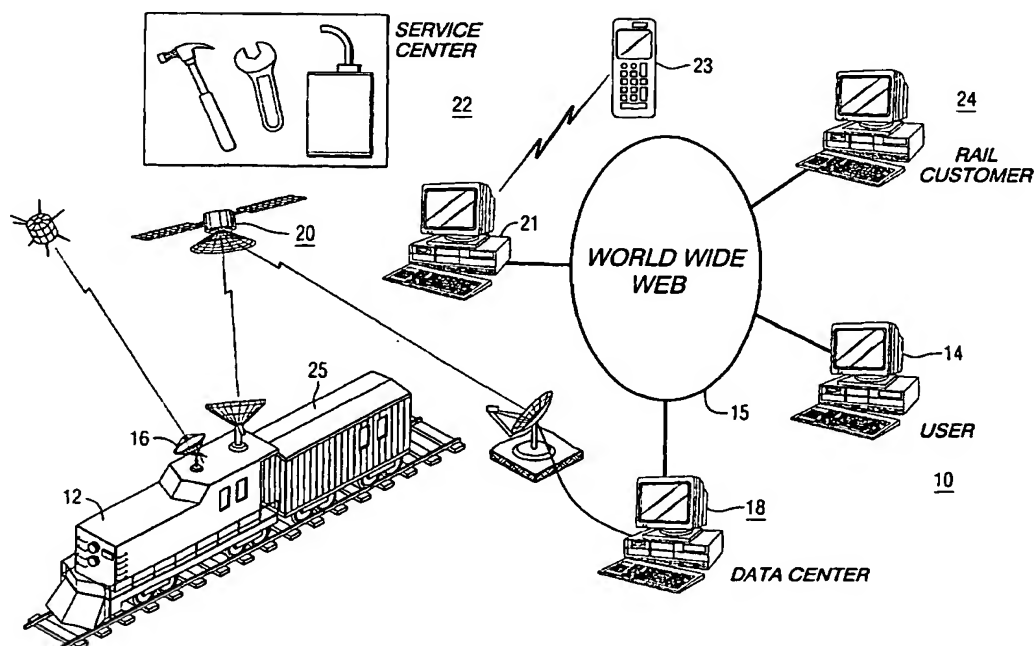
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[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR MANAGING A FLEET OF MOBILE ASSETS



(57) Abstract: A method and apparatus for managing a fleet of mobile assets, such as locomotives (12), utilizing remote data transfer (36, 40), real time data monitoring (122), predictive failure analysis (132), and integrated work order processing (172). A global information network (15) is used to facilitate the communication and presentation of high volumes of data to various parties (14, 18, 22, 24) involved in the process.

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- *with international search report*
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Previous Correction:

see PCT Gazette No. 37/2002 of 12 September 2002, Section II

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/23157

A CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06F17/60

According to International Patent Classification (IPC) or to both national classification and IPC

B FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, INSPEC, IBM-TDB

C DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 737 215 A (SARANGAPANI JAGANNATHAN ET AL) 7 April 1998 (1998-04-07) abstract claims 1-5 column 1, line 12 -column 2, line 4 figures 1-6 ----	1-47
X	WO 98 24042 A (HAO BEILENE ;ELGIN RICHARD L (US); SUNDSTRAND CORP (US); EASTMAN D) 4 June 1998 (1998-06-04) abstract page 1, line 10 -page 10, line 3 ----	1-47
A	US 5 210 704 A (HUSSEINY ABDO A) 11 May 1993 (1993-05-11) abstract claims 1,2 ----- -/--	1-47

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

9 December 2002

Date of mailing of the international search report

13/12/2002

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/23157

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>US 5 845 272 A (BUSH JAMES ARTHUR ET AL) 1 December 1998 (1998-12-01) cited in the application abstract claims 1-8</p>	1-47

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 00/23157

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